WCM 10-MD-03 Examination of Skip Factor Policies: For the Office of the Chief of Naval Operations

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This research was conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

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Executive Summary

According to Department of Defense guidance, skip policy is a medical planning factor describing the percentage of patients that bypass a layer of theater hospitalization, usually understood to be Level 4, while flowing through the casualty care and management system. The evolution of skip policy starts with the policy that requires all patients to have two hospital admissions in theater, implying no skip. At the other extreme, combining Level 3 and Level 4 care into a single "theater hospitalization" category within the taxonomy of care (in the levels of combat care restructuring) suggests a 100% skip policy and minimizes the in-theater medical footprint. The purpose of this effort is to examine skip policy by investigating the underlying factors that influence it, and to determine ways to modify current analytical tools, databases, and procedures to allow better skip policy emulation.

There were three objectives for this effort: (a) identify the medical, physical, and policy factors related to "skipping" and the execution of the medical evacuation mission; (b) conduct a gap analysis to examine current databases and models to identify impediments to the objective examination of the medical evacuation mission in general, and skip policy in particular; and (c) develop a model enhancement plan describing the tasks necessary to overcome the shortfalls identified in the gap analysis.

This paper provides a detailed gap analysis describing the shortfalls found in current modeling capabilities and databases that would hinder the examination of medical evacuation. The results of this gap analysis fell into two categories: data sets and medical models. Gaps in the data sets impede the empirical data analysis process. These gaps range from missing or incomplete data records to inaccurate or miscoded data fields. The evaluation of new data sets and use of additional data repositories will address this issue. Gaps in the medical models consist of deficiencies in the representation of skip policy, making complete skip policy assessments and the execution of medical evacuation missions more problematic. Gaps in this area are primarily incomplete representations of critical factors in the medical models. The model enhancement plan will mitigate the gaps highlighted in this category.

Background

The Office of the Chief of Naval Operations, Assessment Division, Medical Analysis Branch, sponsored a World Class Modeling (WCM) effort to conduct a 6-month study to discover germane factors that influence skip policy, and identify gaps in current modeling capabilities to examine skip policy and the execution of the medical evacuation mission. The purpose of this effort is to identify the theater skip policy components, determine the influence of those components on the execution of the medical evacuation mission, and identify the impediments to the representation of the medical evacuation mission in analytical tools. This paper examines existing modeling capabilities, identifies modeling gaps that currently hinder the examination of medical evacuation (MEDEVAC), and provides mitigation strategies to overcome these gaps.

The WCM initiative is an effort to enhance current modeling capabilities to improve analytic tools used for requirements definition and effectiveness evaluation. The present effort supports the WCM initiative by investigating ways to better evaluate the execution of the MEDEVAC mission, and skip policy in particular.

Skip policy is one of the many medical planning factors used to estimate the patient load during military operations for effectively managing casualty treatment, evacuation, and hospitalization. Broadly speaking, skip policy applies to patients that skip any level of patient care while being processed through the system from point of injury to definitive care. According to Department of Defense (DoD) guidance, skip policy is a medical planning factor describing the percentage of patients that bypass a layer of theater hospitalization (specifically, Level 4) while moving through the casualty care and management system. While many within the DoD medical community view skip policy in its broadest sense, the focus of this analysis is skip policy as described in DoD guidance.

Objectives

The first objective of this effort was to identify the policy, physical, and medical factors related to skip policy. This examination allowed development of metrics to describe skip policy and differentiation between potential skip policies.

The second objective involved examining current databases and extant models to determine the existing capability to characterize and incorporate the factors discovered in the first objective. This assessment identified modeling capability gaps between the current and the needed capability. The results of the gap analysis provided input to the model enhancement plan.

The third objective was to develop a model enhancement plan that described the timing and estimated level of effort necessary to overcome the gaps identified in the second objective.

Methodology

A review of the literature and written guidance was conducted. The official theater skip policy and definitions disseminated prior to, and during, Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) provided a baseline policy, and aided in determining how and if the skip policy evolved over time. This review assisted in identifying policy-driven factors that influenced accomplishing MEDEVAC missions.

OEF and OIF empirical data were examined to assist in identifying the medical factors that influence skip policy execution. This task compared skip-eligible and non-eligible patients to

identify common medical factors, quantified patient injury by condition and acuity, enabled quantification of the medical factors that influence skip policy, and developed patient profiles for skip-eligible patients. The Theater Medical Data Store (TMDS) was the empirical data source for information relating to U.S. combat operations in OEF and OIF. This repository combines data from various reporting systems, and is the most comprehensive collection of deployment-related illness and injury data.

In addition to the various reporting modules that capture and report data to the TMDS, this study used data from the Standard Inpatient Data Record (SIDR) and Standard Ambulatory Data Record (SADR) to describe patients who were evacuated out of theater, primarily to the Landstuhl Regional Medical Center in Germany, and then to the continental United States (CONUS). The SIDR and SADR are the official electronic DoD military data records for inpatients and outpatients, respectively.

The review of theater skip policy doctrine, lessons learned, and other literature resulted in the identification of physical or non-medical factors that influenced medical evacuation. Consultations with subject matter experts further identified factors that determined medical evacuation. These factors identify limitations in modeling fidelity, and are possible model enhancement candidates.

The gap analysis compared policy, medical, and physical factors that influence medical evacuation to current modeling capabilities. The gap analysis provided insight into the ability of present modeling systems to assess the MEDEVAC mission and provided input to the model enhancement plan, thus establishing the foundation to upgrade existing models and close gaps in modeling coverage.

Findings

This section describes the analysis of the policy, medical, and physical factors that influence MEDEVAC execution. This information was used as comparison data.

Factors Analysis—Policy

The Logistics Supplement of the Joint Strategic Capabilities Plan defines skip policy as the planning percentage of patients who will be evacuated directly from operational zone (OPZONE) 1 to OPZONE 3 (Joint Chiefs of Staff, 2005), “skipping” OPZONE 2. OPZONE 1 is the theater of operations or combat zone within a given theater, OPZONE 2 is the communication zone or the area within the given theater that directly supports the combat zone, and OPZONE 3 is CONUS. The key to understanding this definition is that skip policy only applies to patients originating in the combat zone who will not return to duty (RTD) within the theater of operations. Skip-eligible patients are non-RTDs who are clinically capable of skipping Level 4 care or a second hospital admission within a theater.

The evaluations of skip policy over the years have resulted in varying recommendations on what percentage medical planners should use for skip. Currently, the Logistics Supplement of the Joint Strategic Capabilities Plan states that the skip factor default is zero percent for planning (Joint Chiefs of Staff, 2005). This value reflects the results from the 733 Update study, which stated the planning assumption that every patient will have two hospital admissions prior to arriving in CONUS. This is effectively a zero percent skip policy and it represents the “worst case” scenario for in-theater medical requirements.

The acceptance of a zero percent skip factor continued until the evolution of the Force Health Protection vision transitioned from "levels of care" to "taxonomy of care." In this vision, the taxonomy of care eliminated one layer of theater hospitalization, Level 4, with the goal of minimizing the medical footprint in-theater. In short, Level 4 care was eliminated by combining it with Level 3 to form a single category under "theater hospitalization." Elimination of Level 4 care now requires a skip policy re-evaluation, since this restructuring implicitly endorsed a 100% skip policy.

In reaction to the new Force Health Protection vision, services examined skip policy with respect to the restructuring of the casualty care and management system. For example, the clinical study on skip policy conducted by the Army Medical Department (McMurry & Nolan, 2003) focused on Level 4 skip and based all analysis on patient profiles. This study suggested an 80% skip policy. The assumptions used in this study were reviewed and a follow-on analysis was conducted that concluded the skip policy should be 70%, the number currently used by the medical planning community.

Factors Analysis—Medical

In the medical factors analysis, empirical data consisting of patient condition codes were used to provide information on the profile of skip eligible patients during past and current operations. This analysis used data from the TMDS and the U.S. Transportation Command Regulating and Command & Control Evacuation System (TRAC2ES), with a focus on 2005–2008 OEF and OIF combat operations. In contrast to previous skip policy research, this study derived a skip estimate of approximately 12.9% (with a 95% confidence interval of 12.6% to 13.2%) from the data set used in this analysis.

The medical analysis consisted of comparisons among patients who skipped Level 4 with those who did not. Skip patients evacuate out of theater and are never admitted or require evaluation at a Level 4 care facility. These patients typically "stage" at Ramstein Air Base, Germany for convalescent care and then evacuate to CONUS for definitive care. The statements below summarize the results of the OEF and OIF medical analyses.

- Patients who skip have a significantly higher proportion of musculoskeletal disorders of the lower and upper extremities, dislocations, and sprains and strains.
- Injuries in skip patients are primarily minor to moderate severity. The Injury Severity Score (ISS) calculations using the Barell matrix reveal that minor and moderate injuries comprise over 90% of the injuries seen in the skip population during OIF, compared to 59% of minor and moderate injuries in the non-skip population.
- Patients with mental disorders are significantly less likely to skip, while those with pregnancy-related conditions are significantly more likely to skip.
- The skip-eligible patients are primarily disease and non-battle injuries, which make up approximately 91% of the skip population.
- Skip diagnostic distributions by injury or disease *International Classification of Diseases*, Ninth Revision (ICD-9) code do not vary significantly between the two operations.

Table 1 compares the illness and injury distributions by the ICD-9 categories for the skip and non-skip patient groups in OIF, based on analysis of the TMDS dataset. For each ICD-9 category, both the skip and non-skip percentages were computed, together with a combined skip

and non-skip total percentage for the ICD-9 category, and a category skip percentage that indicates the percentage of skip patients within a particular ICD-9 category. The odds ratio for patients who skipped against patients who did not skip because of injury or illness pertaining to a particular ICD-9 category is also provided with an associated 95% confidence interval.

Table 1
ICD-9 Category Distribution of OIF Skip and Non-skip Patients

ICD-9 category	Skip % (*n* = 2,014)	Non-skip % (*n* = 10,689)	Total % (*n* = 12,703)	Category skip %	Odds ratio (95% CI[a])
Musculoskeletal disorders	31.5%	11.6%	14.8%	33.8%	3.49 (3.13,3.90)†
Injury	29.8%	35.7%	34.7%	13.6%	0.77 (0.69,0.85) †
Diseases of the digestive system	4.9%	3.0%	3.3%	23.6%	1.68 (1.33,2.11) †
Diseases of the nervous system	4.1%	3.8%	3.8%	17.0%	1.09 (0.85,1.39)
Neoplasms	3.6%	1.4%	1.7%	33.0%	2.68 (2.02,3.56) †
Ill-defined conditions	3.4%	6.1%	5.7%	9.5%	0.54 (0.42,0.70) †
Diseases of the genitourinary system	3.3%	2.2%	2.3%	22.3%	1.54 (1.17,2.03) †
V-codes	3.2%	1.9%	2.1%	23.9%	1.69 (1.27,2.24) †
E-codes	2.7%	8.4%	7.5%	5.8%	0.31 (0.23,0.41) †
Diseases of the circulatory system	2.3%	3.1%	3.0%	12.2%	0.73 (0.53,1.00)
Mental disorders	2.1%	17.6%	15.2%	2.2%	0.10 (0.08,0.14) †
Diseases of the skin	1.9%	1.0%	1.2%	26.5%	1.93 (1.34,2.80) †
Diseases of the respiratory system	1.7%	1.3%	1.3%	20.1%	1.34 (0.92,1.96)
Congenital anomalies	1.5%	0.4%	0.6%	39.5%	3.50 (2.20,5.56) †
Infectious and parasitic diseases	1.4%	0.5%	0.7%	34.9%	2.88 (1.83,4.53) †
Endocrine, nutritional, and metabolic diseases	1.4%	1.1%	1.1%	19.4%	1.29 (0.85,1.95)
Complications of pregnancy	0.7%	0.3%	0.3%	32.6%	2.57 (1.36,4.88) †
Other	0.2%	0.4%	0.3%	11.4%	0.68 (0.27,1.73)
Diseases of the blood and blood-forming organs	0.1%	0.3%	0.2%	10.0%	0.59 (0.18,1.94)
Perinatal period conditions	0.0%	0.1%	0.1%	0.0%	N/A

[a] CI= confidence interval
†Significant at 5% level

Table 2 below shows the top 10 ICD-9 diagnosis codes among patients who skipped Level 4 care in OIF. About a third of the OIF skip population was primarily musculoskeletal disorders, and dislocations, and sprains and strains.

Table 2
Top 10 ICD-9 Codes for OIF Skip Patients

ICD-9 code	ICD-9 category	OIF skip count (*n* = 2,014)	OIF skip %
722	Intervertebral disc disorders	113	5.6%
724	Other and unspecified disorders of back	103	5.1%
836	Dislocation of knee	99	4.9%
717	Internal derangement of knee	85	4.2%
727	Other disorders of synovium tendon and bursa	60	3.0%
719	Other and unspecified disorders of joint	54	2.7%
844	Sprains and strains of knee and leg	39	1.9%
726	Peripheral enthesopathies and allied syndromes	36	1.8%
733	Other disorders of bone and cartilage	35	1.7%
718	Other derangement of joint	34	1.7%
	Total	658	32.7%

Factors Analysis—Physical

Physical factors are non-medical elements of the medical evacuation mission that have an impact on its execution. The following list describes each factor in brief detail.

- Tactical situation or threat. The nature of the combat operation influences the numbers and types of evacuation assets available. The tactical situation is affected by the type, duration, and magnitude of the operation; the weapons deployed; and the static combat situation.
- Air and ground route security. Evacuation assets are prohibited from operating in unsecured areas until the threats are identified and neutralized.
- Weather conditions. Severe weather conditions can ground or limit the use of air assets in support of the evacuation mission.
- Mechanical issues. Downing events due to mechanical issues delay assets from performing missions and decrease the number of support assets available.
- Anticipated patient load. The number and types of casualties that are expected to require MEDEVAC. Patient populations are affected by the size of the force population at risk, the rate of patient RTD, and the dispersion of warfighters.
- Lift asset availability. Aircraft type and quantity, and the availability of replacements for aircraft that evacuate to CONUS affect the availability of a lift asset to respond to a request.
- Lift capacity. Each type of asset is configured differently to carry a limited number of litter and/or ambulatory casualties. Insufficient capacity to support casualties leads to delays in evacuation.

- Aircraft oxygen capability. Flight regulations require that an asset must contain a sufficient quantity of oxygen to accomplish the planned mission before takeoff. Inadequate amounts or the absence of oxygen could limit the use of the asset for MEDEVAC, which decreases the number of assets available for such missions.
- Infection control concerns. In the event of chemical, biological, radiological, and nuclear warfare, the main objectives are to manage casualties to minimize the effects of agent exposure without exacerbating injuries or illnesses, and limit the number of assets and people that become exposed (Navy Warfare Development Command, 2008). Assets that are exposed to harmful agents are incapable of performing casualty evacuation missions until they are decontaminated. Contamination decreases the number of assets available to support troops during the operation.
- Surgical backlog at a medical treatment facility (MTF). The patient evacuation team is responsible for regulating the medical system, which calls for re-routing air assets when operating rooms at a facility become overwhelmed. Re-routing an air asset could increase the casualty's flight time and impact his/her condition.
- Aircrew duty-time regulations. Duty regulations limit the number of flights a crew member can fly, which limits the number of total sorties for the overall operation.
- Availability of en route care requirements to support "skipping" intermediate levels of care and the impacts on patient survivability. Requirements include personnel, consumables, and equipment that are used to provide patient care while aboard an air asset. The unavailability of these necessities could delay the evacuation of critical patients. Currently, the decisions concerning the impact skipping has on the patient are based on the clinical picture, not the planning picture.
- Staging facilities versus lift assets. The capacities of staging facilities and lift assets should match to ensure that both capabilities can support each other. A staging facility is a location that has the provisions to support patients within the patient movement system. They are staffed by medical personnel and are fixed or mobile facilities that are located close to the flight line. Staging facilities do not have a "treatment" capability. Lift assets are transports used to evacuate casualties from point of injury to more definitive care.
- Throughput of patients at en route stops. An en route stop is a fixed MTF or staging facility that is incorporated in the patient's itinerary. Patient throughput at these stops is affected by the upload and download of aeromedical evacuation aircraft, patient movement items, air routes, inpatient bed capacity, and medical personnel.
- Vehicular support at en route stops. The facility is responsible for vehicular support to enplane and deplane patients and move them via group transport to either a staging facility or an MTF. Insufficient vehicular support increases the time it takes to move patients between facilities and assets, which delays the start and end of flight missions.
- Ability to manage multiple patient loads and/or aircraft at en route care stops. Planners should ensure that there are proper resources to support patients and aircraft at these stops.

Gap Analysis—Data Sets

The TMDS captures data from various reporting modules; this complicates the analysis of individual patients. Additionally, the TMDS uses automated software to assign ICD-9 codes based on narrative text, and, therefore, is less reliable than other data sources. Analysis to identify skip patients based solely on the TMDS will lead to skewed results for the following reasons:

- The TMDS is missing some patient encounter data for the specified period.
- There is missing theater of operation data (the MTF identifier is available, but the MTF description field cannot be relied on to establish the theater of operation).
- Missing deployment data impedes the focus on service personnel deployed in OEF and OIF.
- Missing gender information precludes analysis by gender.
- Miscoded and/or inaccurate primary ICD-9 diagnosis codes on patient record.
- Missing multiple ICD-9 diagnostic does in the TMDS patient record. Only the primary ICD-9 diagnosis code is available in the TMDS patient record. Accurate ISS analysis requires calculating the Barell matrix-based ISS using multiple ICD-9s.
- Deficient means to track if evacuated patients go to Level 4 care or are RTD (only non-RTD patients are a part of the non-skip comparison population).

To compensate for these deficiencies, the deployment file from the Defense Manpower Data Center was merged with the TMDS and data from other sources, including SIDR and SADR. The multiple ICD-9 codes included on patient records in the SIDR and SADR enable ISS derivation. Medical analysis used the patient records in the SIDR and SADR, whose ICD-9 diagnosis codes are validated by certified coders to augment TMDS data. The SIDR and SADR data sets enable determination of which patients were evacuated to CONUS (within a period of 60 days from the encounter date in the TMDS regardless of whether the patient skipped Level 4 care or not). The “skip population” was identified as those patients who were evacuated out of theater, bypassed treatment at Level 4, and who received treatment in CONUS. (Note that the population of patients evacuated to CONUS may not account for patients who skipped Level 4, and who then sought treatment outside the TRICARE medical care program. This exclusion may introduce a slight bias to the analysis.)

The gaps identified above can be effectively mitigated with a hybrid database that uses data from multiple sources to enhance data reliability. The hybrid database—maintained by the Naval Health Research Center (NHRC), San Diego—is an example of this, and it provides a database with the inclusivity of the TMDS while also providing the accuracy of other data sets.

Gap Analysis–Medical Models

The Joint Medical Analysis Tool (JMAT) and the Tactical Medical Logistics Planning Tool (TML+) were the medical modeling tools used for comparison in this study. JMAT is a Joint Staff-approved automated tool with two principal functions: determination of medical support requirements and course of action analysis. These functions allow Combatant Command and Joint Task Force planners and decision-makers to allocate critical medical resources. TML+ is a software program designed for Navy and Marine Corps medical planners as a simulation tool that models the flow of patients from point of injury through more definitive care, and as an

operations research tool that supports medical systems analysis, risk assessment, and field medical services planning. When discussing the shortfalls of medical models, the identified gaps may apply to either JMAT or TML+, or both.

Modeling capabilities do not allow emulation of skip policies based on patient condition and/or severity. The present implementation of skip policy uses a pre-defined value to represent the percentage of patients that skip from Level 3 care to Level 5 care. This technique applies this percentage to all patients regardless of patient classification (i.e., wounded in action, disease, or non-battle injury), condition, or severity. The results from the medical factors analysis indicates that skip-eligible patients exhibit a certain patient profile. This profile depicts patients with musculoskeletal disorders and injuries ranging from minor to moderate severity, but whose injuries preclude return to duty and perhaps require lengthy rehabilitation. This patient population subset represents a small portion of the total patient population (approximately 13% of disease and non-battle injury patients). The use of a static value to represent a skip policy for all patients could lead to inaccurate interpretations of the behavior and results of the model.

Emulation of en route care services onboard evacuation assets is currently lacking in extant medical models. These models capture the execution of en route care services by estimating the use of certain patient movement items, but do not account for medical support personnel or availability of aircraft-mounted MEDEVAC support equipment or supplies. The consumption of supplies is only a minute part of the en route care system, and offers little insight into how this system of personnel and equipment impacts patient outcomes.

Currently, medical models do not adequately account for the various significant delays that can occur during a mission, such as a breakdown, preventative maintenance, and weather. Fidelity is limited to the application of a mission delay factor, which is an estimate of total delay that is applied to all missions. The use of the mission delay approach does not capture the impacts of asset unavailability because of planned and/or unplanned events to the patient movement system and patient outcomes

Current models are deficient in the emulation of resource utilization and patient throughput at staging facilities. Staging facilities are integral to the patient movement system. These facilities do not offer medical care services, but do provide support to patients as they move from one MTF to the next. Currently, medical models represent staging facilities through facility entities that contain staging beds to represent the holding capacity. These entities do not include other resources like personnel, equipment, and supplies, which help provide support to patients while visiting staging facilities, and they do not emulate the patient funneling at staging facilities while awaiting to board an aircraft. The absence of these resources and of this patient flow inhibits examination of the impact of staging facilities on the patient movement system.

In addition to lacking the ability to emulate patient throughput at staging facilities, current models are also deficient in representing throughput of the airfield to include: ground transportation assets at the airfield, patient loading and unloading capability at the aircraft, aircraft availability constraints of the airfield, and competing demands of the airfield to support other missions. Constraints on throughput will likely have the single greatest impact on determining a supportable skip policy within a given network of patient movement capabilities.

Finally, it should be pointed out that no model currently exists which simulates medical treatment from point of injury through Level 5 care. This fundamental flaw inhibits full examination of skip from a modeling perspective. For example, TML+ models point of injury

through Level 3 care and JMAT models Level 1 through Level 4. The greater complexity of specialized care (from both an equipment and procedural point of view) will likely make it impossible to emulate the full spectrum of care. Enhancements to extant models should focus on improving the capability of the analyst to emulate skip policies within the levels of care the model covers, vice attempting to expand the coverage level.

Conclusion

Workarounds, future enhancements, and procedures mitigate the effect of the gaps explained in the Gap Analysis sections above. The final objective of this effort is to develop a model enhancement plan to address the impediments identified in the gap analysis. This section provides a generalized review of the mitigation strategies that are described in the model enhancement plan (below).

Data Sets

The skip analysis for both OEF and OIF operations reveals a declining skip trend over the period of 2005–2008. As follow-on work, a trend analysis on data from 2008 through the present should occur when those data are available. To provide further clarity, the follow-on skip analysis should use the TRAC2ES data, which contains operational theater and patient personally identifiable information. Patient personally identifiable information permits tracking of patients through the levels of care. For both OEF and OIF, this analysis (which was based on TMDS data augmented by SIDR and SADR data) reveals a consistent skip medical profile distribution.

Medical Models

Gap analysis indicates the following deficiencies:

- use of a static skip policy for all patients regardless of condition and/or severity,
- absence of emulation of the medical services rendered onboard assets and at staging facilities,
- inability to simulate the unavailability of assets because of planned and/or unplanned events,
- absence of patient flow process emulation at staging facilities and airfields, and
- incapability to emulate the movement of patients from Level 1 through Level 5 care.

A common problem among these gaps is the lack of appropriate detail in depicting critical elements of the patient movement system in medical models. Most analyses address these misrepresentations through the careful formulation of assumptions or through clever “workarounds”; however, with the focus on the execution of MEDEVAC missions other (more permanent and repeatable) means should be considered. The following modifications to current medical models are strategies to mitigate the impediments identified in the gap analysis:

- add flexibility to models to allow skip policies to vary by patient condition and/or severity;
- add task profiles, personnel, supplies, and equipment data sets onboard evacuation assets to simulate the usage of en route care resources;
- add asset unavailability options to account for significant planned and/or unplanned delay events; and

- add staging facility and airfield entities along with task profiles, personnel, supplies, and equipment data sets to simulate the throughput of patients and the use of resources while providing support to patients at these facilities.

Model Enhancement Plan

The purpose of the model enhancement plan described in this section is to establish a blueprint for software implementation, test, and qualification for TML+ enhancements. These enhancements provide mitigation to the impediments identified in the gap analysis. The implementation of these enhancements will enable TML+ to effectively emulate MEDEVAC missions and evaluate the impact of skip policy on the casualty care and management system.

The model enhancement effort described in this plan will follow the TML+ software development process. The software development process for the TML+ project includes:

- requirements determination,
- conceptual design development,
- design implementation,
- software testing,
- update and/or create support documentation creation and /or updating,
- software release, and
- maintenance.

This model enhancement plan describes the activities, level of effort, and cost necessary to implement the TML+ enhancements.

Requirements Determination

The requirements determination phase of the software development process involves gaining a clear understanding of the requirements, through interaction with the customer. During this phase, several aspects of the design are considered, including input and output requirements, user interaction components, and changes to software. The main goal during this phase is to acquire an understanding of the new system functionality requirements. Broadly speaking, the requirements are captured in the mitigation strategy and can be summarized as follows:

- skip policies that vary by patient condition and/or severity,
- use of en route care resources onboard evacuation assets,
- asset unavailability options to account for significant unplanned delay events,
- new staging facility and airfield entities with appropriate holding and throughput capacities, and
- use of resources while providing support to patients at staging facilities.

In the following subsections, this plan addresses each enhancement by providing a brief description and discussing the data and software development activities needed for completion.

Skip Policy Data Development

The skip policy enhancement is a modification that will allow the user to vary skip policies based on patient condition and/or severity. The analysis of the medical factors revealed that only a small subset of patients with certain conditions are eligible to skip. Currently, a skip factor is applied to the entire patient population. This model enhancement will add flexibility and realism by allowing the user to specify which patients are eligible for skip, and by assigning to them skip policy percentages rather than applying a static percentage to the total patient population.

Two data sets will be needed to complete this enhancement. These data sets include skip policy percentages by condition and/or severity. The skip policy percentages should be "user settable" or could be derived from the empirical data that was used to support this study. Additional analysis is required to obtain the ISS data.

Skip Policy Software Development

Currently, TML+ has a feature that allows the user to define evacuation rules for patients based on patient condition, patient classification, previous visited functional area, and deceased status. These evacuation rules direct patients along particular routes within the patient movement system. The model enhancement will include the addition of an evacuation rule that will be based on skip policy percentages and will be user editable.

En Route Care Data Development

The en route care model enhancement will provide TML+ with the ability to emulate the medical services rendered onboard evacuation assets. En route care services are performed by specialized teams of medical personnel who provide medical support to critical patients while in transit. These teams are limited in quantity and must travel with critical patients from one facility to the next. This enhancement will apply constraints on the throughput of critical patients through the patient movement system because of the limited quantities of these required resources.

This model enhancement completion will depend on the creation of task profile, personnel, supplies, and equipment data sets for the United States Air Force en route care services.

En Route Care Software Development

Code modifications will be needed to enable TML+ to emulate the resource use onboard air assets. Evacuation assets will need to inherit properties from medical facilities that will enable the assets to render treatment to patients. This new functionality will have to be integrated with the died of wounds algorithm.

Evacuation Asset Unavailability Software Development

The evacuation asset unavailability model enhancement will enable TML+ to account for significant unplanned delay events, such as weather, mechanical issues, and other causes. These delay events are random and do not occur during every mission; therefore, the mission delay functions are not appropriate for these delays because mission delays occur before and/or after every mission. Implementing this model enhancement will provide TML+ with the ability to model these random events and apply constraints on the number of mission-capable assets.

The addition of a mission capability rate metric and a delay table to the transport properties window will assist in the completion of this enhancement. The mission capability rate will be a

decimal number that represents the probability that the transport is available for the evacuation mission. A delay table, similar to the lift of opportunity delay table, will provide a distribution of the time delay when an asset is declared unavailable during the simulation. Both the delay table and the mission-capable rate will depend on user input and be independent among evacuation assets in the scenario.

Staging Facility Data Development

The staging facility model enhancement will involve the creation of a staging facility entity and emulating the resources use at that facility. Staging facilities are en route care stops that provide support, not medical treatment, to patients while traveling through the patient movement system. The critical aspect of staging facilities that impact evacuation missions is the patient throughput at these facilities. This enhancement will enable TML+ to capture the patient throughput while emulating the process flow of patients and the support services at these facilities.

The completion of this model enhancement will depend on the creation of task profile, personnel, supplies, and equipment data sets for fixed, contingency, and/or mobile aeromedical staging facilities. Also, data on the holding capacities for the various types of staging facilities will be gathered.

Staging Facility Software Development

Currently, there is a medical facility entity called a collection point. This entity will serve as a basis for the staging facility. The collection point is a medical facility entity that does not provide medical treatment but acts as a drop-off and pick-up point for evacuation assets. The collection point also does not constrain the number of patients in the facility at one time. The staging facilities will be collection points with personnel, supplies, equipment, and treatment profiles. These facilities will have fixed holding capacities based on the type of staging facility and will be user editable.

Airfield Software Development

The airfield model enhancement will involve the creation of an airfield entity and emulating the aircraft throughput at these areas. Airfield throughput, combined with aircraft availability will produce a maximum supportable throughput for a given transportation node within the network. Implementing this model enhancement will provide TML+ with the ability to emulate the airfield throughput.

The airfield entity will also be based on the collection point. This entity will have user-editable options that define the maximum on-ground for aircraft, the maximum time limit an aircraft can remain at an airfield, the maximum sortie rate, and an airfield availability schedule.

Conceptual Design Development

After determining the requirements, the development team will establish a conceptual design of the enhancements. The conceptual design will provide detailed specifications, including the required changes to the model, user interaction components, input and output requirements, risks associated with changes, and location of changes within model. These details are usually written up in a design document (see the Design Documents subsection) and presented to the customer for feedback. The design specifications outlined in the design document must be approved by all stakeholders before the implementation phase commences.

Implementation Management

The implementation management phase refers to the activities and tools used to monitor and manage the process of implementing the model enhancements discussed in this plan. Configuration management (CM) and project monitoring are the two management practices used to perform these activities.

Configuration Management

CM is the practice of managing changes to a software system to maintain the integrity of that system over time. CM involves evaluating proposed changes, tracking the status of changes, and maintaining the system and support documents. This model enhancement effort will use the TML+ project CM plan.

The TML+ project CM plan utilizes Microsoft Team Foundation Server (TFS) as the configuration management system. TFS keeps version and history information for the source code files, software support documentation, and all other configuration items within the TML+ project. The CM plan specifies these items as the TML+ application, user's manual, methodology manual, release notes, data dictionary, and software releases.

The CM plan also describes the process of reviewing and prioritizing possible changes to the model. The 10 steps below describe change request (CR) implementation.

1. Team member initiates a CR in TFS.
2. Project manager assesses the impact of the proposed CR to the project
3. Project manager rejects the CR or requests approval from the change control board.
4. Project manager creates a task in TFS to implement an approved CR.
5. Project manager schedules the task into development cycle
6. Project manager assigns the task to a developer.
7. Developer completes the task.
8. Tester tests the system to verify the task completion (see the Verification Testing subsection).
9. Tester closes the CR in TFS once testing is complete.
10. CR is included in a new TML+ release at the end of the development cycle.

Project Monitoring

Project monitoring is keeping track of a project's progress over time. This practice involves monitoring activities, communicating status, and taking corrective action. The TML+ project executes the project monitoring practice through monthly status reviews with stakeholders and senior level management. During these reviews, the status of milestones and tasks are reported and issues are discussed. The purpose of this practice is to ensure that the project is performing according to schedule and budget, and to address issues and seek corrective action early. This model enhancement effort will follow the project monitoring plan defined for the TML+ project.

Software Testing

After the implementation of the model enhancements, the software system will undergo a series of tests. These tests are to ensure that the software program performs according to specifications

and provides the correct output. The following subsections describe the various types of test conducted during the testing period.

Verification Testing

Verification testing is the process of ensuring that a software system complies with specifications, and that the code is free of bugs and errors. This type of testing is completed by examining the behavior of the system to ensure that the system satisfies expectations. Verification testing for TML+ occurs during the last week of each development cycle.

Validation Testing

Validation testing is the process of ensuring that a software system fulfills its intended purpose and provides useful output. This testing examines the system output to check for accuracy and usefulness. TML+ validation testing will occur during this effort.

Regression Testing

Regression testing is the process of evaluating the functionality of the software program to ensure that changes have not created new errors. This type of test is usually conducted after a major change to the software system has occurred. Regression tests are conducted for the TML+ project before every public release and/or after a major change to the software program. TML+ regression testing will occur during this effort.

Software Support Documentation

The TML+ support documentation will be updated and/or created to reflect changes to the software program. Documentation is written text that explains how a software system operates or how to use it. The TML+ support documentation includes: the methodology manual, the user's manual, the verification and validation report, and the design documents. The following subsections describe these documents and how they are impacted by this enhancement effort.

Design Documents

For each TML+ modification, developers will create a design document. The design document is typically a set of PowerPoint slides or a written report that illustrate the requirement and the proposed implementation. This could include database schema, classes, graphical representations of user interfaces or information flow, and any other information relevant to implementation. The design documents will be useful for documenting verification tests because they provide a direct description of how the software should behave.

Methodology Manual

The methodology manual is a detailed reference describing every technical aspect of the model. The methodology manual for TML+ describes:

- model architecture,
- models and objects that perform during the simulation,
- data import and validation,
- mortality modeling, and
- key mathematical algorithms used throughout the simulation.

NHRC and the TML+ developers maintain the TML+ methodology manual. The methodology manual will be updated to reflect any modifications that affect the model's technical aspects.

User's Manual

The user's manual describes, in detail, how to use the tool and interpret the tool's output. The user's manual provides troubleshooting guidelines, software support information, and general help content. NHRC and the TML+ developers maintain the TML+ user's manual. The user's manual will be updated to include the model enhancements implemented in this effort.

Verification and Validation Artifacts

Verification and validation artifacts are documents or other evidence that verification and validation activities occurred. These artifacts will include records of verification tests, validations tests, and any remedial actions and will be maintained in TFS.

Software Deployment and Maintenance

The final steps in the model development process are deployment and maintenance. Deployment is the releasing of a new version of the software for consumer use. The enhancements implemented in this effort will be included in TML+'s next release. Maintenance refers to the process of maintaining and enhancing the software system to handle any issues discovered within the system or new requirements. This phase of the development process is on-going throughout the life of the software system.

Schedule and Level of Effort

Development of the model enhancements described in this plan will require 4 months to complete. The effort will include all the tasks in the software model development process including (a) requirements determination, (b) conceptual design development, (c) design implementation, (d) testing, (d) documentation, (f) deployment, and (g) maintenance. Figure 1 proposes a schedule for the 4-month development effort.

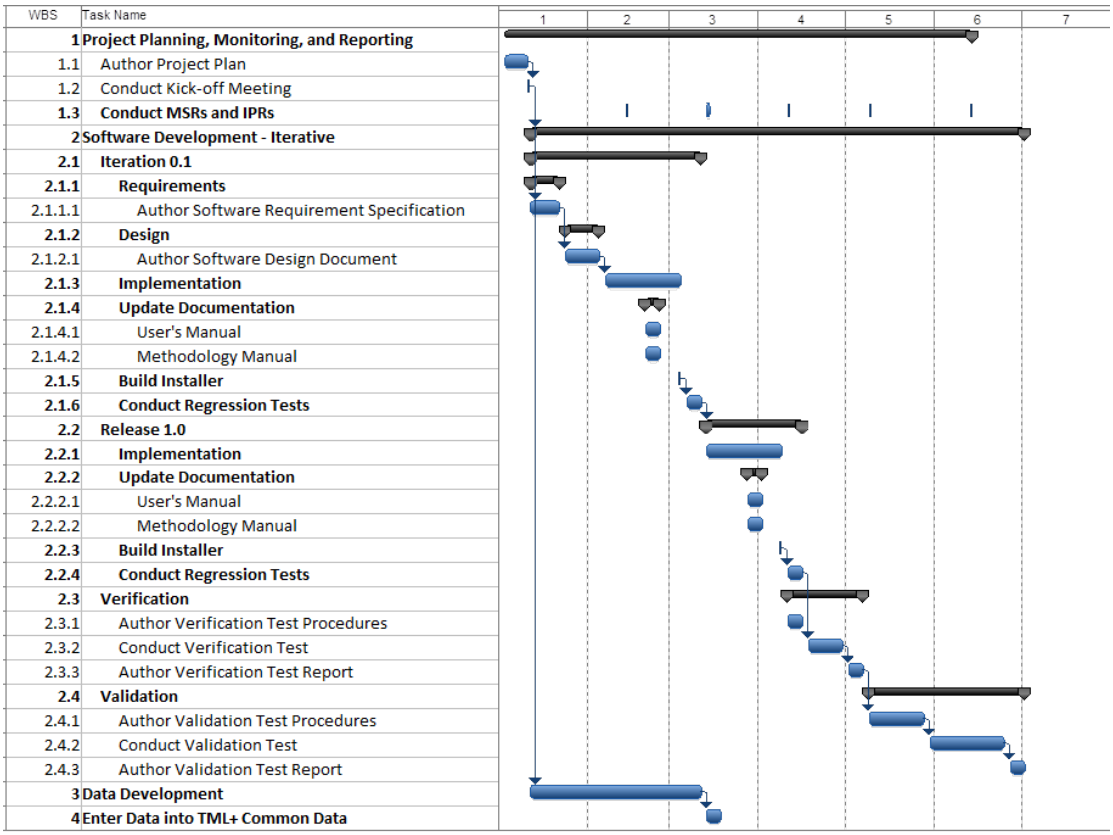

Figure 1. The proposed TML+ enhancement schedule.

Table 3 summarizes the level of effort per contributor, with a rough order of magnitude cost estimate of $205,000.

Table 3
Estimated Level of Effort

Staff	Level of effort (man months)
Program manager	0.5
Programmer (C++, C#)	4.0
Medical statistician	2.0
Medical subject matter expert	2.0
Operations research analyst	4.0

Summary

The overall goals of this effort are to obtain a better understanding of skip policy, and to improve the ability of existing tools and databases to capture the impacts of skip policy on MEDEVAC missions. These goals are achieved through investigations into the underlying factors that influence skip policy, evaluations of the capabilities of current modeling tools to emulate the

execution of MEDEVAC missions, and the development of approaches that will enable current modeling capabilities to overcome any weaknesses uncovered in those evaluations.

The analysis of the policy, medical, and physical factors that influence skip policy provides information on the observed and written meaning of skip and its interaction with other elements within the patient movement system. Literature reviews provide information on how the meaning and use of skip policy has evolved over time because of doctrine changes. Empirical data evaluations help develop medical profiles of those patients that are eligible to bypass a second admission to a theater hospital. Consultations with subject matter experts provide details on the non-medical elements of the patient movement system that affect skip policy and MEDEVAC missions. The results from the factors analysis serve as comparison data in the gap analysis.

The gap analysis evaluates the capability of current modeling tools to emulate skip policy. There are two categories of capability shortfalls identified as data sets and medical models. The impacts of each gap to future analyses are described in detail within this report, but the model enhancement plan section only provides mitigation strategies for the gaps listed in the medical models category.

The model enhancement plan provides possible strategies to mitigate the shortfalls identified in the gap analysis. These strategies will help enable current analytical tools to effectively emulate skip policy and capture the impacts of skip on MEDEVAC missions. Proposed model enhancements include:

- enabling models to apply skip policies that vary by patient condition and/or severity,
- emulating the usage of en route care resources onboard evacuation assets,
- applying mission capability percentages to evacuation assets to account for unplanned downing events, and
- emulating patient throughput at staging facilities and airfields.

A follow-on effort will address the implementation of the model enhancement plan.

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Appendix A
Acronym List

CM	configuration management
CONUS	Continental United States
CR	change request
DoD	Department of Defense
ICD-9	*International Classification of Diseases,* Ninth Revision
ISS	Injury Severity Score
JMAT	Joint Medical Analysis Tool
MEDEVAC	medical evacuation
MTF	medical treatment facility
NHRC	Naval Health Research Center
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OPZONE	operational zone
RTD	return to duty
SADR	Standard Ambulatory Data Record
SIDR	Standard Inpatient Data Record
TFS	Microsoft Team Foundation Server
TMDS	Theater Medical Data Store
TML+	Tactical Medical Logistics Planning Tool
TRAC2ES	U.S. Transportation Command Regulating and Command & Control Evacuation System
WCM	World Class Modeling

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14. ABSTRACT

Skip policy is a medical planning factor describing the percentage of patients that bypass a layer of theater hospitalization, usually understood to be Level 4, while flowing through the casualty care and management system. The purpose of this paper was to examine skip policy by investigating the underlying factors that influence it, and to determine ways to modify current analytical tools, databases, and procedures to allow better skip policy emulation. This paper provides a detailed gap analysis describing the shortfalls found in current modeling capabilities and databases that would hinder the examination of medical evacuation. The results of this gap analysis fell into two categories: data sets and medical models. Gaps in the data sets impede the empirical data analysis process. These gaps range from missing or incomplete data records to inaccurate or miscoded data fields. The evaluation of new data sets and use of additional data repositories will address this issue. Gaps in the medical models consist of deficiencies in the representation of skip policy, making complete skip policy assessments and the execution of medical evacuation missions more problematic. Gaps in this area are primarily incomplete representations of critical factors in the medical models.

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